Gulf of Mexico Gas Hydrates JIP Cruise Prospectus

Characterizing Natural Gas Hydrates in the Deep Water Gulf of Mexico: Applications for Safe Drilling and Production Activities

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Disclaimer

This prospectus is based on precruise planning and advice from the general scientific community, advisory panels, and JIP participants. During the course of the cruise it may be scientifically or operationally advantageous to amend the plan detailed in this prospectus. Any proposed changes are contingent on approval of JIP project management.

Abstract

During Phase II of the four-year collaborative project funded by the U.S. Department of Energy and the Joint Industry Program (JIP) we will drill and core sediments believed to contain gas hydrates in the offshore Gulf of Mexico (GOM). The logging, drilling and coring to total depths ranging from 307 to 553 m beneath the sea floor will take place in two different offshore lease areas, Atwater Valley 13/14 and Keathley Canyon 151, in water depths in the range of 1280 to 1330 m. Shallow coring (<6 m) has recovered sediment with gas hydrate composed of dominantly microbial methane at or near both of the proposed coring localities. Seismic evidence in the form of a faintly defined bottom-simulating reflection (BSR) indicates possible occurrence of gas hydrates at depths of 390 to 440 m beneath the seafloor at the Keathley Canyon locality. Preliminary shallow coring and heat flow surveys at the proposed coring localities indicate a complicated sub-seafloor hydrologic system with variable salinities and temperature.

Cruise and project objectives include (1) calibrating geophysical estimates of location and concentration of hydrate and underlying free gas concentrations; (2) determining physical properties (e.g., strength, permeability, compressibility) of hydrate-bearing and underlying sediments in order to evaluate the relationship between gas hydrates, fluid flow, and seafloor/slope stability; (3) evaluating the sources and transport mechanisms for gas and the physical and chemical mechanisms of hydrate formation near the seafloor and at the base of the gas hydrate stability zone; (4) collecting samples of gas hydrate preserved at *in situ* pressures for investigation both during and post-cruise; (5) collecting and preserving pore water, gas, and sediment samples for post-cruise geochemical and microbiological investigations; and (6) developing a better basis for understanding the impact of gas hydrates on offshore petroleum drilling and production operations.

At each of the deep coring localities, the sites will first be evaluated by logging while drilling (LWD) to accurately record physical properties in a gauge hole and identify regions of possible gas hydrate occurrence prior to coring. The LWD results will be used to refine deployment of pressure coring equipment and tools to measure in situ temperature and pressure. Non-pressurized cores will be immediately scanned with an

infrared camera to detect cold spots indicative of dissociating hydrate prior to sectioning the cores, sampling for gas and pore water analysis, and routine characterization of physical properties using the multi sensor core logger (MSCL). Pressurized cores will be maintained at *in situ* conditions for investigation with a variety of transfer chambers, logging devices, and probes. The cruise plan also includes wireline logging after completion of coring at each of the deep coring holes, and vertical seismic profiles in one hole each at Keathley Canyon and Atwater Valley.

Introduction

Gas hydrate, an ice-like compound of natural gas and water, is widespread on the Gulf of Mexico continental slope (Milkov and Sassen, 2001) and has been sampled mainly near the seafloor and at shallow depths of burial under water depths in the range of 540-2000 m. Hydrocarbon gases from underlying petroleum deposits and microbial methane generated and buried with rapidly deposited sediments are venting to the sea floor and crystallizing as gas hydrate under the low temperatures and pressures that prevail. The geology of the northern Gulf of Mexico is complicated by deformation of underlying Mesozoic salt caused by rapid accumulation of thick Cenozoic sediment. Hydrocarbon generation from underlying petroleum source rocks is recent and ongoing, and faults and fracture zones provide migration conduits for flow of petroleum and brines to the seafloor. Sassen et al. (2002) discuss the relation of gas hydrate occurrence to fluid venting and sediment deformation. Publications by Salvador (1987) and Worrall and Snelson (1989) provide additional background on the geology of the northern Gulf of Mexico.

Gas hydrate formation changes the properties of the sediment and may be a geologic hazard if petroleum development activities cause gasification of the hydrate. This project is developing borehole stability models and seismic analysis methods pertinent to gas hydrate containing sediments in the Gulf of Mexico. Prior work (Phase I) was devoted to site survey data collection and analysis, and model development to enable detection and characterization of gas hydrate containing sediments in the Gulf of Mexico. The field program (Phase II) will be devoted to drilling, logging, and coring of gas hydrate containing sediments with subsequent core and log analysis to test, validate and adjust the models.

Site Selection

Two areas (OCS lease blocks) were selected with multiple sites in which to study different modes of gas hydrate occurrence – Atwater Valley 13/14 (AT 13/14), and Keathley Canyon 151 (KC 151). Both areas are at water depths of about 1300m. The AT 13/14 region has mounds on the seafloor and evidence of fluid/sediment intrusion and venting. The KC 151 block contains one of the rare instances of a bottom-simulating seismic reflection (BSR) in the Gulf of Mexico, and may indicate the occurrence of gas hydrates at depth. A summary with examples of the seismic data used to select these sites is given in a separate report (Dugan and others, 2003). The drilling/coring/logging program will be carried out in riserless mode using the semisubmersible vessel ***Uncle John***. The Minerals Management Service (MMS) has agreed to permit the holes under rules for science related holes >150m deep. The MMS has also agreed that JIP holes (about 307-553m) do not have to be cemented as part of the abandonment unless a flow of gas is observed, or a zone of free gas is logged. The general locations of the proposed JIP coring/logging sites are shown in Figure 1.

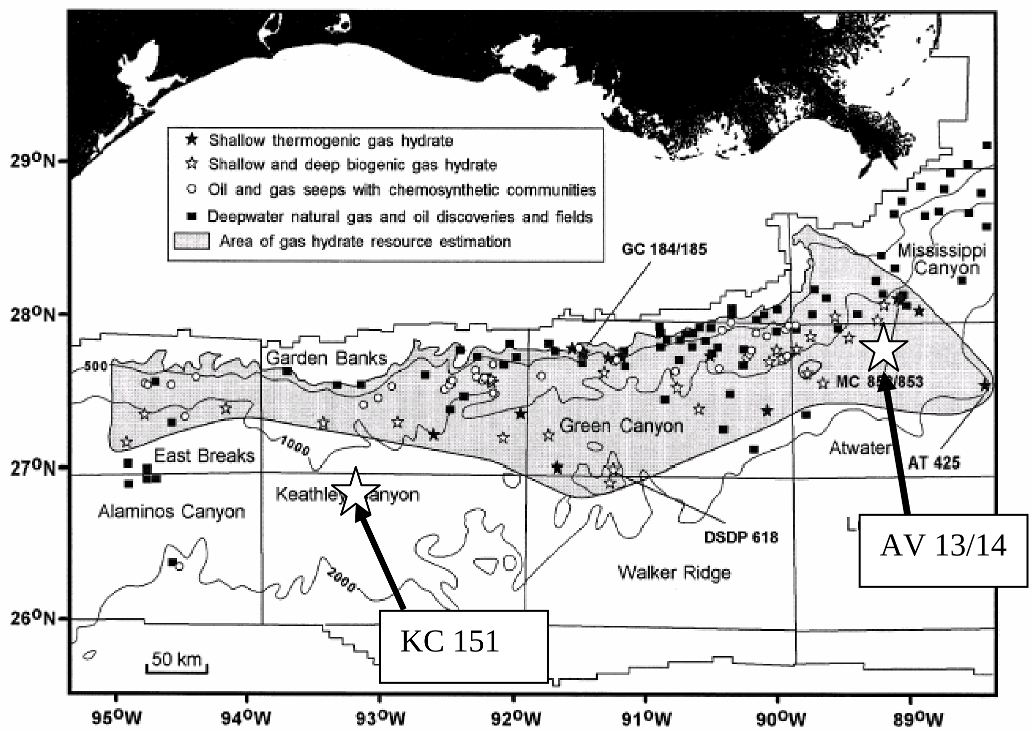

Figure 1. Map showing location of planned JIP coring/logging sites relative to gas hydrate sites and petroleum occurrences in the Gulf of Mexico (modified from Milkov and Sassen, 2001). Water depth contours shown in meters.

During Phase I of this project a series of meetings were devoted to site surveys and site selection. The sites initially selected on the basis of seismic data were adjusted slightly based on a shallow hazards survey conducted by ChevronTexaco and presented at a meeting in New Orleans (Site Selection Meeting, 2-4-2004). All of the sites evaluated for planned Phase II deep coring and logging holes are listed in Table 1. Only those sites (AT1, AT2, KC1, KC3) shown with proposed MMS hole designations are planned for coring and logging.

In addition to the site locations in Table 1 based on seismic and hazard site surveys, a series of shallow (30-m penetration) holes on and near a presumed hydrate mound (Mound F) were added to the main Atwater Valley logging and coring program. The site locations for the mound shallow coring program are listed in Table 2. Only two sites (ATM1, ATM4) will be cored.

A seismic line crossing the proposed sites at Atwater Valley 13/14 is shown in Figure 2.

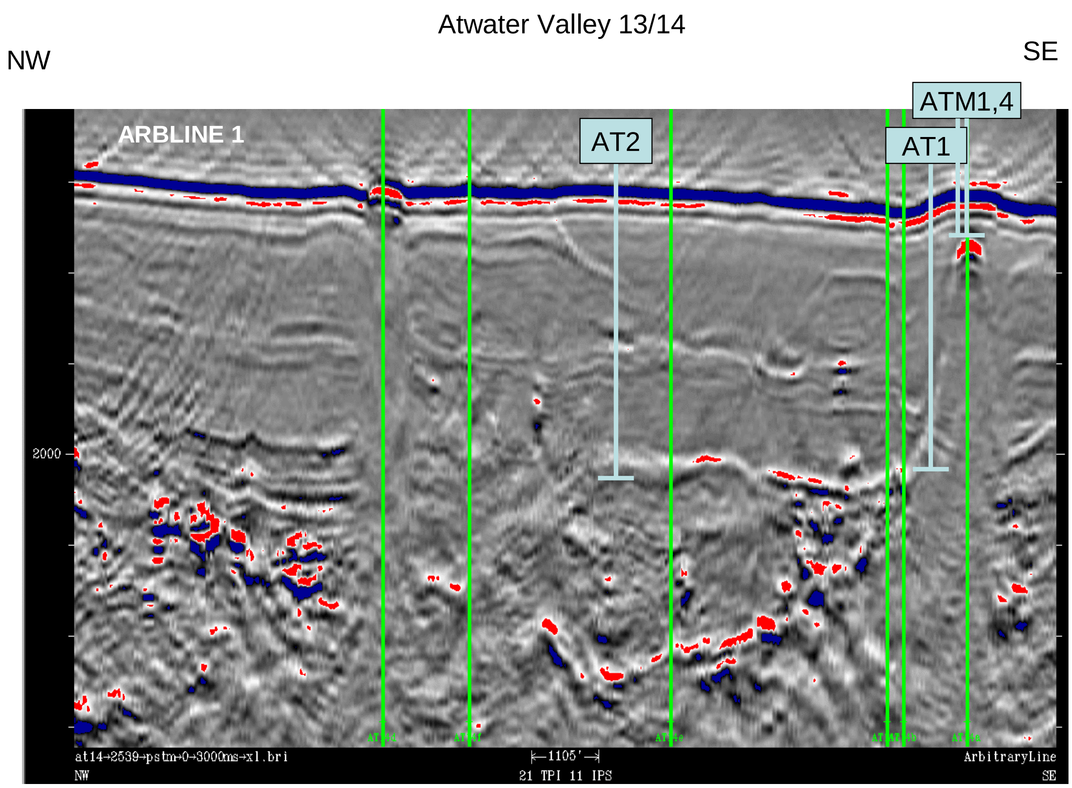

Figure 2. Seismic line (ARBLINE 1) through proposed Sites AT2, AT1, ATM1, ATM4. Continuous vertical (green) lines indicate earlier proposed site locations. Total depths indicated are approximate.

The main objective at AT2 is to penetrate continuous, undisturbed, low reflectivity sediments, a regional unconformity, and underlying disturbed, high amplitude sediments. AT1 will penetrate the side of an intrusive feature that is capped by an amplitude anomaly believed to represent free gas. Sites ATM1 and ATM4 are shallow (30 mbsf) coring sites into a mound previously shown to contain gas hydrate.

The objectives at Keathley Canyon 151 are focused on possible gas hydrate occurrence associated with a BSR. A seismic line through the Keathley Canyon 151 proposed sites is shown in Figure 3.

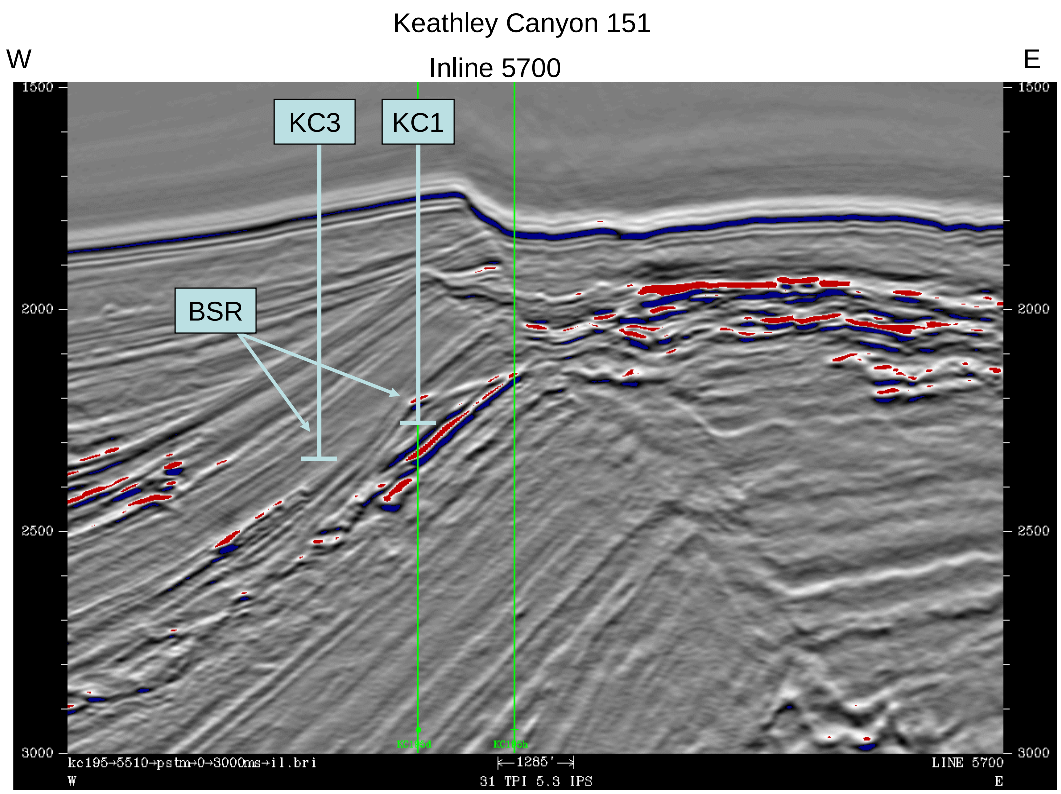

Figure 3. Seismic line (Inline 5700) through proposed Sites KC3, KC1 with position of BSR indicated. Total depth shown is approximate.

Operations Plan

The Phase II drilling/logging/coring program is planned for about 37 days in the April/May 2005 time period. April/May was chosen as the time most likely to involve minimal weather problems. A tentative operations plan with time estimates is given in Table 3, which summarizes more detailed time estimates (A. Conte, Timesummary.xls).

Drilling and Logging Plan

Deployment of four coring tools is planned during the GOM JIP. These tools are of two types:

A) Non-Pressurized Cores

1. Fugro Hydraulic Piston Corer (FHPC) approx 4.5 or 9 m long
2. Fugro Corer (FC) – approx 4 m long

Normally the FHPC is used in softer formations and the FC used in stiffer formations where the FHPC cannot fully penetrate.

B) Pressurized Cores

3. Fugro Pressure Corer (FPC) 1 m long
4. HYACE Rotary Corer (HRC) 1 m long

The FPC is likely to be used more in softer formations whereas the HRC is designed primarily for use in harder, more indurated formations. In practice it is likely that there will be a wide range of sediments in which both tools can be successfully used.

Most cored intervals will be about 4.5 or 9 m long, which are the lengths of standard FHPC core barrels. In other cases, the drill string will be "washed ahead" without recovering sediments in order to advance the drill bit to a target depth where core recovery will be resumed.

Drilled intervals are in meters below rig floor (mbrf), measured from the kelly bushing on the rig floor to the bottom of the drill pipe, and meters below seafloor (mbsf), calculated from the mbrf depth of the seafloor. The resulting core top data in mbsf as calculated from the length of the drill pipe will be the ultimate reference for any further depth calculation procedures for cores and samples within cores.

Scientific Objectives

Although JIP project objectives are aimed primarily at improving remote detection of gas hydrates and predicting stress, pressure, and temperature response of hydrate-bearing sediments, the coring and logging of deep water sediments in the northern GOM affords the opportunity of testing a variety of assumptions related to marine gas hydrate occurrence. Some of these assumptions include:

- Sulfate gradients in shallow sediments can be used to indicate presence of underlying gas hydrates.

- Gas hydrate development requires enhanced methane transport from deeper sediments.
- Anaerobic methane oxidation limits methane flux to the overlying ocean.
- Shallow amplitude anomalies above apparent gas chimneys indicate presence of warm fluid intrusions that elevate isotherms and cause the base of gas hydrate stability to occur at shallow depths.
- Gas chimneys are primarily related to high gas flux and levels of gas saturation of sediments that permit free gas to coexist with gas hydrate within the gas hydrate stability zone.
- High salinities in shallow sediments are related to brine flux from underlying salt intrusions.
- High salinities are related to salt exclusion associated with rapid gas hydrate formation in shallow sediments.
- Fluid flow and shallow gas hydrate occurrence are related to fluid pressure and rock property distributions (pore pressure, porosity, consolidation, permeability, shear strength).
- Sediment slumping and slope instability is related to rapid sedimentation rate, consolidation behavior and shallow overpressure.

Samples and data collected by the JIP cruise will permit testing of these and other hypotheses.

Coring and Sampling Strategy

The detailed coring program and science plan is contained in a multi-page spreadsheet (ScientificPlan-vers. 11.xls). The first tab gives the location information shown in Table 1. The next four tabs outline the logging while drilling (LWD) program for each of the deep holes. The nest six tabs give the coring program, shipboard sampling program, and shipboard experiments planned for the six coring holes. The remaining tabs indicate responsibilities, staffing, post-cruise experiments, supplies, objectives summary and well plan.

Curatorial Procedures and Sample Depth Calculations

The JIP boreholes will be named according to MMS conventions (AT13 #1-2, AT14 #1-4, KC151 #1-4). Cores taken within each borehole are numbered sequentially, with a letter indicating the type of coring tool (H = FHPC, C=FC, P=FPC, R=HRC). Sections within each core are numbered sequentially from the top, and samples within sections are identified by centimeter interval measured from the top of the section. A full curatorial identifier for a JIP sample consists of the hole identification, core number, core type, section number, and centimeter interval. For example, a sample identification of JIP AT13 #1-1H-1, 10–12 cm, represents a sample removed from the interval between 10 and 12 cm below the top of Section 1. The core is 1H (H designates a core was taken with the FHPC coring tool), the borehole designation is AT13 #1 drilled during the JIP cruise. The curatorial mbsf of a sample is calculated by adding the depth of the sample below the section top and the lengths of all higher sections in the core to the core top datum measured with the drill string.

A sediment core from less than a few hundred mbsf may, in some cases, expand upon recovery (typically 10% in the upper 300 mbsf), and its length may not necessarily match the drilled interval. In addition, a coring gap is typically present between cores. Thus, a discrepancy may exist between the drilling mbsf and the curatorial mbsf. For instance, the curatorial mbsf of a sample taken from the bottom of a core may be larger than that of a sample from the top of the subsequent core, where the latter corresponds to the drilled core top datum.

If a core has incomplete recovery, all cored material is assumed to originate from the top of the drilled interval as a continuous section for curation purposes. The true depth interval within the cored interval is not known. This should be considered as a sampling uncertainty in correlation of cores with downhole logs.

Core recovery and sample log sheets (clipboard, paper, pen) will be maintained during the core processing and sampling operations in the core processing van, and later transferred to the cruise data management system (Excel spreadsheet, Access database).

Non-pressurized Core Handling (FHPC and FC)

Cores that might contain gas hydrates should be recovered as quickly as possible. An ice bath may be used in some cases to slow the dissociation process. A core reception/preparation van will be on the deck of the ***Uncle John*** where individual cores (perhaps up to 9 m long) can be laid on ‘core hooks’ and quickly drilled, labeled and sectioned. Infrared (IR) camera imaging will be done as soon as practical after core recovery. Both track-mounted and hand held IR cameras will be used to identify the position in cores of cold spots, indicating possible zones of hydrate occurrence.

If gas hydrates are present or if dissolved gas contents of sediments exceed about 10 mM, gas expansion voids will form in the core and pressure must be relieved to prevent extrusion of the core or possible explosive shattering of the core liner. Pressure is first removed by punching holes in the core liner at the position of the gas voids to sample gases by syringe attached by a stopcock to a core liner penetration tool. After or while gas samples are collected, holes can be drilled at regular (~50-cm) intervals along the core to permit degassing. Where cold spots indicate possible presence of gas hydrates, whole round sections of 10-15 cm length may be cut, capped, wrapped and immediately preserved in liquid nitrogen dewars. Cores with IR-temperature anomalies may also be subjected to X-ray CT scanning to provide high resolution, 3D images of sediment hydrate structures. Some gas hydrate containing cores may be decomposed under controlled conditions to measure gas yields and provide samples for gas analysis.

After cores have degassed (and if necessary restored to approximate original length) the cores will be measured and cut into nominal 1-meter sections. The whole-round core sample (10-20 cm in length) for interstitial water analysis should be cut from the top of the specified section (or shifted somewhat to provide optimal sample quality), and the 5-cm^3 plug of sediment for headspace gas analysis taken from the base of the opposite section. Whole round samples (8-10 cm in length) for microbiology will be taken from specified cores and stored under refrigerator (4ºC) or freezer (-80ºC) conditions.

After the minimum sampling of specified intervals for ephemeral properties and microbiology, the whole-round core sections should be logged using the multi sensor core logger (MSCL). Properties to be measured by MSCL include gamma ray density, P-wave velocity, magnetic susceptibility, and electrical resistivity. The general core flow plan is shown in Figure 4.

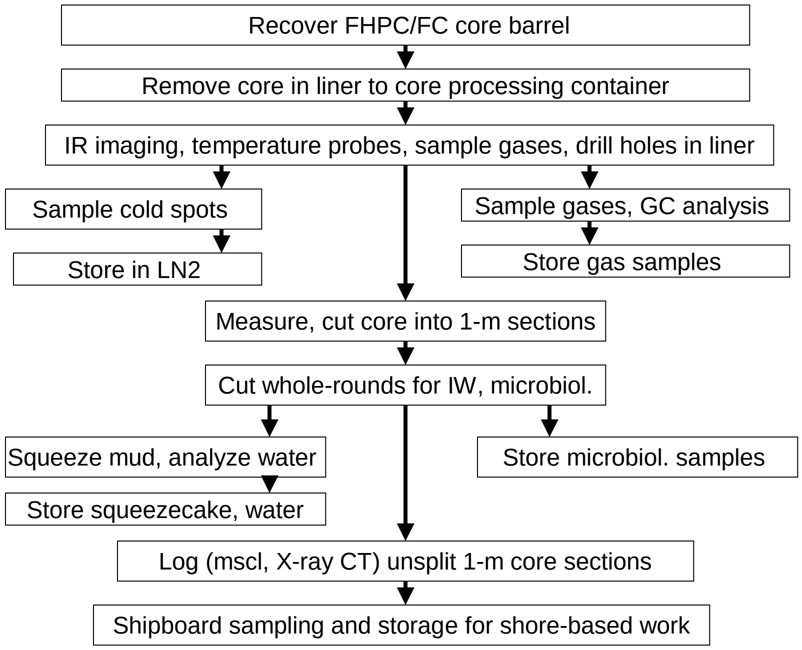

Figure 4. Core flow plan for non-pressurized cores.

Pressure Core Handling (FPC and HRC)

It is crucial that autoclaves potentially containing gas (dissolved or free) and/or gas hydrate are kept close to in situ conditions (temperature and pressure) to prevent gas hydrate dissociating, gas exsolving and pressures rising in the pressure vessels. Consequently, the coring tools and autoclaves will be immersed in an ice bath as soon as possible after arriving on the rig floor. Once temperature and pressure are stable (around in situ conditions) the autoclave will be removed and connected to a cold Shear Transfer Chamber (STC) in a cold van and the core transferred into a HYACINTH Storage Chamber (SC). Once inside the SC the core can be either logged in the X-ray CT or the MSCL-V, or connected to the cold MSCL-P (Multi Sensor Core Logger – Pressure) for high-pressure measurement of physical properties.

The X-ray CT can provide very rapid 2D and 3D information on the sediment texture while the core is under pressure in the aluminum SC’s and can reveal the presence of gas, water and massive gas hydrate layers or nodules. The MSCL-V will provide an accurate 1D density profile of the core through either the steel SC's or the aluminum SC's and can reveal the presence of gas, water and massive gas hydrate layers or nodules. The MSCL-P can be used with either of the 2 CMCs. One CMC was specially developed to enable measurements of Vp, Vs, electrical resistivity, and strength/resistance of the core through holes in the core liner. The other CMC was developed to log Vp automatically and rapidly through the core liner.

While the X-ray CT logging provides valuable information on the contents of pressure cores, there is some concern that multiple transfers could compromise the MSCL-P measurements. Alternate trials on initial cores will help determine the optimal procedures for shipboard logging and experiments with pressurized samples.

Apart from rapidly assessing the overall nature of the contents of any individual pressure core inside an aluminum SC, the X ray CT may determine the spatial distribution of hydrates contained within the core. This might be assessed at either in situ pressures (if the hydrate is relatively massive) or as a result of sequential imaging during dissociation experiments (if the hydrate is more dispersed in nature). The X-ray CT logging system complements the MSCL-V and will be fitted into the same cold container.

One decision in processing pressure cores is to decide whether the quantity, nature, distribution and physical properties of hydrates inside the core are to be assessed by controlled measurements and dissociation inside pressure vessels. Alternatively the general nature and distribution of hydrates could be determined by rapid depressurization and visual observation with subsequent decomposition and sampling of the gas and water. It is possible to depressurize cold cores rapidly to get immediate access to a relative undisrupted gas hydrate core. The major problem is not the dissociation of gas hydrates (as this is a relatively slow process) but with the more rapid process of exsolution of gas dissolved in the pore water. Experience from Leg 204, where pressure was rapidly released around a frozen core, indicates this is feasible and can be done safely.

With pressurized cores, close to in situ conditions, any gas hydrates inside are stable and hence initial measurements from all logging instruments can be made enabling informed decisions about how each core is to be subsequently processed. Undoubtedly the best science and understanding will come from a combination of techniques and procedures.

Figure 5 shows the core flow plan for pressure cores, and Table 4 lists the equipment that will be used during the cruise to evaluate physical properties.

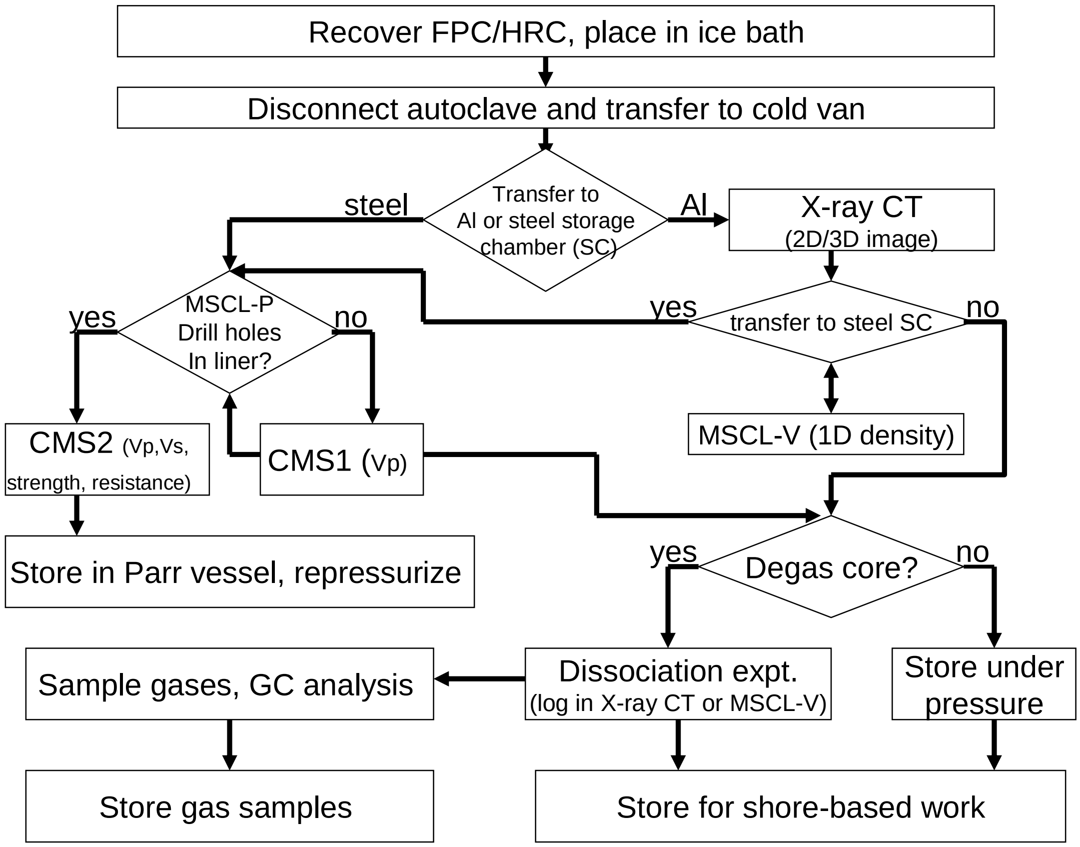

Figure 5. Core flow plan for pressurized cores. All permutations of experiments are not shown.

Shipboard Geochemical Analyses

Gas samples recovered from cores will be analyzed by gas chromatography on the ship and preserved for subsequent more detailed (chemical and isotopic) shore-based analyses. Interstitial waters squeezed from cores will be analyzed onboard for salinity, dissolved sulfide, alkalinity. Water samples will be subdivided for more detailed analyses at Scripps and Rice.

Downhole Temperature and Pressure Measurements

In addition to coring operations, *in situ* temperature and pressure will be measured at 3-8 depths in each hole. Temperature measurements yield data that:

a) Constrain near seafloor geotherms for correlation with the traditional heat flow data collected in the shallowest ~5 m of sediment;

b) Constrain the thermal gradient as a function of depth with the ultimate goal of determining advection rates through joint analysis of pore water chemistry (conservative species) and temperature data;

c) Constrain temperatures near the BSR (when applicable) and below the BSR in the largely unexplored free gas zone;

d) Provide temperature data at the same depth as piezoprobe measurements for (1) later joint analysis of in situ T and pore pressure; (2) testing the reliability of the piezoprobe temperature sensor.

Fugro's piezoprobe was used successfully on ODP Leg 204 to measure pressure in silts/shales. Pressure (piezoprobe) measurements will document *in situ* conditions. These measured pressures can then be used for comparison with laboratory studies that interpret *in situ* pressure based on consolidation behavior.

Logging Strategy

LWD tools will be deployed to TD at sites AT2 (AT13 #1), AT1 (AT14 #1), KC3 (KC151 #1), and KC1 (KC151 #2) to obtain high-quality porosity and density (VDN) logs, various resistivity, and gamma radiation (resistivity at the bit [RAB] with imaging). The RAB images should be useful for pinpointing gas hydrate–bearing zones. In addition to directly addressing the primary cruise objectives, the LWD information will be critical for planning subsequent leg activities, such as locating intervals where the pressure core (FPC, HRC) tools might be used as well as positioning for temperature and piezoprobe experiments.

Wireline logging will be performed at the same four sites (AT2, AT1, KC3 and KC1) previously drilled with LWD and selectively cored. The standard (dipole sonic) will be deployed, with possible additional tools depending on the budget available. Vertical seismic profile (VSP) experiments will be conducted in two holes (AT2 and KC1) with the required wireline tools to record the experiments. Acoustic velocity logs (along with the VSPs) are critical in determining the velocity structure associated with the BSR. Depth-to-seismic ties will also be accomplished by means of synthetic seismograms computed from density, sonic logs, and VSPs. This correlation can be made using standard logs to measure the density, porosity, and compressional velocity of the sediments. Both *P*-wave and *S* -wave velocity measurements will be made using the standard dipole sonic imager (DSI) tool. Sediment permeability may be estimated using temperature gradients and heat flow changes by running temperature, porosity, and resistivity (dual induction tool [DIT]) logs.

Summary of Objectives and Criteria for Success

The Gulf of Mexico Gas Hydrates JIP, in collaboration with NETL/DOE, is investigating naturally occurring gas hydrates in the Gulf of Mexico (GOM). The goals of the JIP include:

1. Develop and implement a research and technology plan to assist characterization of sediments containing naturally occurring gas hydrates in deepwater in the GOM
2. Assess and understand potential safety hazards associated with drilling wells and running pipelines through sediments containing gas hydrates
3. Develop a database of existing seismic, core, log, thermophysical and biogeochemical data to identify current hydrate containing sites in deepwater GOM
4. Use existing knowledge to choose one or more sites in deepwater GOM for field tests
5. Plan and execute a drilling and sample collection field testing program to collect data and obtain cores to characterize the hydrate containing sediments in the GOM
6. Use existing data in the database and data collected from the field during the project to develop wellbore and seafloor stability models pertinent to hydrate containing sediments in the GOM

The first four objectives have been largely completed, and this document summarizes plans for the cruise/field testing program. The success of the cruise will be determined by the extent to which gas hydrate containing sediments can be logged, cored, sampled, preserved, and investigated both during and after the cruise. If there is limited recovery of gas hydrate in cores, a priority list has been designated for distribution of the limited samples, shown in Table 5.

Table 5 lists all of the planned investigations, and some are not appropriate for, or do not require cores of hydrate containing sediment, but the list does provide a sense of prioritization for cruise objectives.

Gas hydrates generally are not uniformly distributed throughout the sediments, but appear to grow preferentially at nucleation sites within zones that are methane-saturated with respect to hydrate stability. Because the pressure coring tools capture a limited volume of sediment (1-meter core length) it is possible (or likely) that some of the 30-odd deployments of pressure coring tools will not recover gas hydrate. Moreover, when gas hydrate-containing sediments are cored with the non-pressurized tools, it is possible that the cored gas hydrates will not survive the retrieval trip through the water column to the deck of the ship. Thus there is some risk that gas hydrate core recovery will limit the ability to successfully complete all of the objectives.

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Table 1. Phase II JIP sites selected by seismic and shallow hazard surveys.

	Line	Trace	X UTM	Y UTM	Latitude	Longitude	Water depth (m)	Penetration (m)	Borehole Name (MMS) LWD hole	Borehole Name (MMS) Core hole
AT1	2562	7064	904181.4443	10145035.55	27° 56' 15.4" N	89° 16' 50.3" W	1289	307	AT14 #1	AT14 #2
AT2	2615	6997	901438.1894	10148521.86	27° 56' 49.4" N	89° 17' 21.6" W	1281	315	AT13 #1	AT13 #2
AT3	2587	7032	902875.1376	10146676.43	27° 56' 31.4" N	89° 17' 05.2" W	1290	305		
AT4	2662	6936	898930.1735	10151609.96	27° 57' 19.5" N	89° 17' 50.2" W	1280	241		
AT5	2556	7071	904470.2928	10144646.25	27° 56' 11.6" N	89° 16' 47.0" W	1283	90		
KC1	5700	20280	1644827.03	9733112.408	26° 49' 22.6" N	92° 59' 11.3" W	1311	609	KC151 #2	KC151 #3
KC2	5700	20320	1646466.2	9733112.615	26° 49' 22.6" N	92° 58' 53.2" W	1369	369		
KC3	5700	20248	1643513.88	9733112.29	26° 49' 22.6" N	92° 59' 25.8" W	1333	553	KC151 #1	KC151 #2
KC4	5601	20460	1652209.674	9726613.782	26° 48' 18.2" N	92° 57' 49.8" W	1265	344		
KC5	5601	20323	1646593.956	9726612.564	26° 48' 18.2" N	92° 58' 51.8" W	1271	512		
KC6	5601	20391	1649383.7	9726613.074	26° 48' 18.2" N	92° 58' 21.0" W	1288	434		

Table 2. Proposed Atwater Valley shallow coring program.

Proposed Site	X UTM	Y UTM	Latitude (^{o}N)	Longitude (^{o}W)	Water Depth (m)	Penetration (m)	ID (MMS) Core hole
ATM1(AT14a)	904551.770	10144646.351	27.93656	89.27947	1297	30	AT14 #3
ATM2(AT14b)	903891.800	10145458.819	27.93876	89.28156	1312	30	
ATM3(AT14c)	903731.256	10145683.677	27.93937	89.28207	1309	30	
ATM4(AT5)	904470.293	10144646.254	27.93655	89.27972	1283	30	AT14 #4

Table 3. Planned JIP operations and time estimates.

Site	operations description	days	cumulative days
Mobile	transit to AT2	1.5	1.5
AT2	Hole AT13 #1: LWD to 315 mbsf	2.0	3.5
	reposition to AT1	0.2	3.7
AT1	Hole AT14 #1: LWD to 307 mbsf	2.0	5.7
AT1	Hole AT14 #2: drill, spot core to 307 mbsf, 7 pressure cores, 3 piezoprobe tests. Wireline log with DSI	4.0	9.7
	reposition to ATM1	0.2	9.9
ATM1	Hole AT14 #3: core to 30 mbsf including 2 pressure cores.	0.5	10.4
	reposition to ATM4	0.2	10.6
ATM4	Hole AT14 #4: core to 30 mbsf including 2 pressure cores.	0.5	11.1
	reposition to AT2	0.2	11.3
AT2	Hole AT13 #2: drill, spot core to 315 mbsf, 7 pressure cores, 3 piezoprobe tests. Wireline log with DSI and VSP	4.0	15.3
	Transit to KC3	1.5	16.8
KC3	Hole KC151 #1: LWD to 460 mbsf	2.5	19.3
	reposition to KC1	0.2	19.5
KC1	Hole KC151 #2: LWD to 410 mbsf	2.5	22.0
KC1	Hole KC151 #3: drill, spot core to 410 mbsf, 7 pressure cores, 3 piezoprobe tests. Wireline log with DSI and VSP	7.0	29.0
	reposition to KC3	0.2	29.2
KC3	Hole KC151 #4: drill, spot core to 460 mbsf, 7 pressure cores, 3 piezoprobe tests. Wireline log with DSI	6.4	35.6
	transit to Galveston	1.4	37.0

Table 4. Summary of shipboard core logging equipment.

MSCL-S	**Standard Multi Sensor Core Logger**	Logs gamma density, P wave velocity, electrical resistivity and magnetic susceptibility. Used to log all the regular cores (FHPC) and any HRC or FPC cores that are suitable when de-pressurized.
MSCL-V	**Vertical Multi Sensor Core Logger (equipped only with gamma density system).**	provides gamma density profiles of HYACINTH pressure cores, in either the steel storage chambers or in the new Al storage chambers.
MSCL-P	**Pressurized Multi Sensor Core Logger with optional central measurement chambers CMCs.**	CMC1 provides continuous, automatic, rapid Vp profiles through the liner. CMC2 provides, Vp, Vs, electrical resistivity and strength through holes cut in the liner.
XCT	**X-ray CT scanner**	provide x-ray CT scans on HYACINTH pressure cores in specially fabricated Al storage chambers as well as on FHPC and FC cores. Cores can be dissociated while being logged in with sequential, time series gas samples being collected for analysis. Alternatively they can be stored in the steel storage chambers for shore-based studies.
	Hydrate dissociation equipment	Mariotte bottle style displacement flowmeters will be used for measuring gas produced during hydrate dissociation studies. Both thermal and pressure swing dissociation studies can be performed on board in the XCT or the MSCL-V.

Table 5. Hydrate Core Priority if sample quantity is low.

First Priority

Mechanical Testing (Georgia Tech, Rice, USGS Woods Hole, Fugro)
- Stress-strain curves
- Tensile strength
- Shear Strength
- Compressive strength
- Young's moduli
- Shear moduli
- Bulk moduli
- Poison's ratio
- failure/stability envelopes
- permeability
- shear strength (mini-vane)
- Triaxial Compression
- Constraint modulus

Gas analysis (USGS Menlo Park and Scripps)
- C6+
- Isotope

Second Priority

Seismic properties (Georgia Tech and USGS Woods Hole)
- P and S-wave velocities
- acoustic impedance

Geological (Rice, Georgia Tech, LBNL); note that most of these are being done on the ship.
- Distribution of hydrates within sediments
- Pore filling
- Pore Pressure
- In-situ Temperature
- Optical observation / analyses
- Hydrate Type (Raman spectroscopy)

Third Priority

Reservoir (USGS WH & NETL)
- Dissociation
- Kinetic rate constants

Formation Water (Scripps, Rice, USGS Menlo Park, Fugro)
- pH
- Complete analysis
- Pore water extraction
- Electrical conductivity / ionic concentration

Thermal (Georgia Tech, USGS Woods Hole, Fugro)
- Thermal conductivity
- Thermal diffusivity
- Heat capacity

Fourth Priority

Sediment Description (Scripps, USGS Woods Hole, Rice, Georgia Tech, Fugro)
- Chemical analysis
- Grain size
- water content
- grain density
- specific surface area
- Density
- Clay mineralogy
- organic content

Electrical (USGS Woods Hole, Georgia Tech, Fugro)
- Resistivity
- real permittivity at microwave frequencies

Fifth Priority

Biological (Scripps, NRL, Georgia Tech, PNNL)
- Methanogens
- Clone library